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Mobile Peer-to-Peer Content and Community Models

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1   Introduction

Mobile peer-to-peer applications are being envisioned as exciting new content applications for next generation's mobile wireless networks. Peer-to-peer applications on the fixed-line Internet are experiencing strong demand and rapid diffusion. However, wireless peer-to-peer applications are likely to be very different.

Mobile peer-to-peer applications are still a predominantly conceptual phenomenon. Successful applications are not easy to imagine. Mobile phones have limited storage and restricted input capabilities, making them inconvenient to initiate queries; prices for mobile data transmission are too high for customers; and while Internet file sharing offers the huge databases of other users around the globe, mobile file sharing may rather be restricted to local environments, for example, to ad hoc social networks.

These factors suggest that mobile peer-to-peer file sharing will be different from traditional fixed-line file sharing and will serve different needs. This chapter will discuss what value mobile communications can add to peer-to-peer applications and vice versa. The analysis will focus on the technological characteristics of mobile peer-to-peer applications, content models between user generated and professionally produced content, the concepts of identity and community in the context of mobile communications, and media companies' challenges and options to effectively manage mobile peer-to-peer communities. A discussion of emerging policy issues in the context of mobile peer-to-peer communities concludes the chapter.

2   Technological Characteristics of Mobile Peer-to-Peer Applications

Mobile peer-to-peer applications via handheld devices differ technologically from fixed-line desktop PC or notebook peer-to-peer applications. Dennis

and Ash (2001) suggest that technological platforms are the dominant feature of the identity of new media. Therefore, this section will analyze the technological characteristics.

2.1   Definition and Categorization of Mobile Peer-to-Peer Applications

Peer-to-peer applications in fixed-line environments are defined as a range of applications that harness the free resources available at the edges of the Internet such as storage, cycles, content, and human presence (Shirky, 2001).[1] Three applications helped define the strengths of fixed-line peer-to-peer: Napster, which created a peer-to-peer file sharing system; SETI@home, an initiative of the Search for Extraterrestrial Intelligence which turns a group of disparate computers into a supercomputer; and ICQ, the original instant messaging program (Shirky, 2002).

Mobile peer-to-peer applications can be defined as a range of applications that harness (a) ad hoc interaction through human presence and physical proximity; (b) virtual storage through distributed content availability on mobile Internet appliances in both public and private environments; and (c) shared broadband access through bandwidth sharing. The devices used for peer-to-peer applications are expanding from stationary to mobile. The PC and other stationary devices have large processing and storage capabilities. Mobile devices, however, have limited processing, battery, and storage capabilities. They are, for example, not suited for building a personal media library. Similarly, display size and input facilities of a mobile information device do not offer convenient browsing and searching opportunities in mobile settings. Moreover, cellular networks do not offer the bandwidth needed to transfer large files and is expensive (see Brown, in this volume). For a systematic discussion of the challenges and potentials of mobile peer-to-per applications it is useful to categorize potential applications.

Fattah (2002) offers a categorization of peer-to-peer applications that differentiates active applications and idle utilizations. Active applications comprise user collaboration such as file sharing, gaming, and Electronic Data Interchange (EDI). Idle utilizations consist of resource utilizations such as bandwidth conversion and of supercomputing for high-performance applications. Wireless peer-to-peer applications can follow this differentiation into active and idle utilizations (see Figure 1). Active applications comprise user collaboration such as mobile ad hoc file sharing, mobile instant messaging, or mobile multiplayer gaming as well as application interaction such as Bluetooth-enabled data exchanges. Idle utilizations comprise resource utilizations
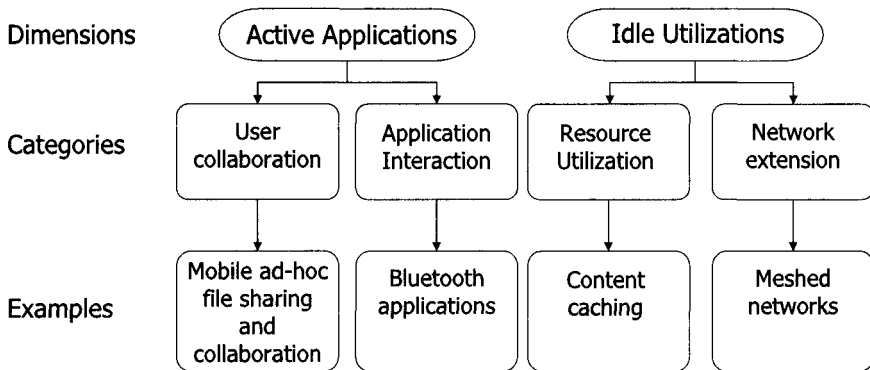
Wireless Peer-to-Peer Applications

Dimensions	Active Applications		Idle Utilizations	
Categories	User collaboration	Application Interaction	Resource Utilization	Network extension
Examples	Mobile ad-hoc file sharing and collaboration	Bluetooth applications	Content caching	Meshed networks

Figure 1: Categorization of wireless peer-to-peer applications
Source: adapted from Fattah (2002), p. 23

such as caching content and the extension of wireless networks for meshed networks.

Idle utilization applications may become more promising for wireless peer-to-peer applications. Yet, for the discussion of the role of mass media content for mobile peer-to-peer applications we will focus, for the remainder of this chapter, on the first application category of user collaborations.

2.2 Mobile ad hoc Networks

Mobile sharing applications may become available through wireless ad hoc networks based on physical proximity. Mobile ad hoc networks are decentralized and self-organizing. They are dynamic and continuously reshaped into multiple clusters. These mobile devices interact as autonomous peers (Kortuem et al., 2001; Gruber, Schollmeier, & Kellerer, 2004). Personal area networks (PANs) are a special category. They are low power and low range wireless networks that connect personal mobile devices or wearable computers. The devices function as nodes for peer-to-peer networks or as hosts for the most frequently accessed information.

The focus of data sharing can, for example, lie on increasing the data availability to users roaming a metropolitan area (Papadopouli/Schulzrinne, 2001; Wolfson, Xu, & Sistla, 2004). In this case, the networks need no support of any infrastructure for data dissemination among the mobile devices. There-

by, they overcome intermittent connectivity to the Internet and allow location-dependent and collaborative services. The relevant parameters are the density of cooperative hosts and their mobility. Particularly in urban environments users increasingly demand ubiquitous data availability. In these environments, mobile ad hoc peer-to-peer networks can be used to cache popular content.

Mobile ad hoc information systems are particularly interesting, because personal area networks allows integrating mobile devices into everyday social interaction. Peer-to-peer applications for proximity-aware mobile collaboration can augment social encounters and face-to-face interactions. However, in mobile ad hoc networks, time becomes a critical resource. The exchange of information is bound to happen fast as physical presence is required. If a transfer takes too long, the network connection might be interrupted. Therefore, Kortuem et al. (2001) suggest to exchange URLs that point to files on a server rather than the files themselves.

3 Mobile Peer-to-Peer Content Models

The basic premise of sharing applications is that consumers have something valuable to share. It is useful for the discussion of content models to differentiate two organizational levels of content production: professionally produced, user-generated content. Each will be discussed in turn.

3.1 User-Generated Content

Personal media files such as digital pictures, voice recordings, or short video sequences may offer the highest incentive to swap digital files with peers and friends. Since storage is not a distinctive feature of mobile personal devices, user-generated content may be transient. However, mobile peer-to-peer platforms can serve as virtual storage that makes personal media files ubiquitously and instantaneously accessible.

Sharing of personal data as an expression of connectivity with peers and friends may become an essential revenue driver for mobile operators. Communications and message services already produce substantial revenue. Connectivity has always mattered more than (professionally produced) content (Odlyzko, 2001). In the 19th-century, for example, postal services derived their profits from letters and subsidized newspaper distribution. E-mail is creating a lot of value in the Internet, although its popularity was not fore-

seen by the ARPANET's planners. The perceived prominence of connectivity over content can be used today to explain the widespread adoption of SMS and raise questions about premium data services of next generation 3G networks. Odlyzko (2005) even suggests that the main role of 3G wireless systems should be to stimulate voice usage. However, the willingness to pay for connectivity may also extend to sharing personal media files.

An essential incentive for personal file sharing may lie in the user's identity representation within social networks. A distinguishing element of mobile environments as opposed to virtual environments on the fixed-line Internet is that the identity of the user is rather enforced than blurred. The sociologist Sherry Turkle (1997) has suggested that users on the fixed-line Internet deliberately choose multiple identities that include gender switch and different communication intentions. In contrast, the mobile phone with its distinct telephone number and SIM card that stores personal information reinforces the identity of its user. The personality representation in mobile wireless environments is given via the device that can represent user and lifestyle (Pedersen, Nysveen, & Thorbjørnsen, 2003). Personalized style elements include the cell phone, but also content elements such as certain ring-tones or icons as personality representations when sending an SMS. Thus, the concept of identity is of particular interest in mobile communications environments (Feldmann, 2005).

Research on SMS suggests that mobile communications is predominantly used to maintain existing personal relationships with a rather small group of peers. Youth send SMS in more than 50% of all cases to partners or best friends; they rarely write to family members or strangers, both below 10% (Hoeflich & Roessler, 2001). Another study reveals that youth exchange SMS regularly with 1-3 persons in 40% of the cases, with 7 to 9 persons in 20% and with more than 10 persons in only 4% of the cases (Schlobinski et al., 2001). A study surveying 9 European countries (Smoreda & Thomas, 2001), shows that contact patterns are strongly concentrated geographically, whereas Internet-based written contact is far more dispersed.

This user behavior suggests that file sharing via mobile phones may be particularly interesting for user-generated media. Such file sharing is different from the fixed-line global file sharing among a group of anonymous users. Identity construction in personal networks may become a strong proposition for mobile peer-to-peer usage. Such a development would also avoid many of the intellectual property right issues of stationary peer-to-peer file sharing.

3.2   Professionally Produced Media Content

In the fixed line Internet, music, movies, and TV series are the most popular media content for file sharing. For mobile devices, however, only a small amount of mobile media content is available at the moment that could be used to create a mobile peer-to-peer community. Mobile content and services are subject to licensing agreements between media companies and mobile operators and usually not intended to allow content sharing. The costs of securing these mobile content rights, for example, for sports highlights, are not negligible and they are currently limiting the media content and services carriers can offer.

In the light of this background, three options for mass media content may emerge: (1) promotional sample contents; (2) user-contextualized content, and (3) branded content.

Sample content is a viable sharing option for professionally produced content that can be used as a promotional tool. It may become linked with subsequent purchasing options. For example, music firms could release twenty seconds of a new song that is available for sharing and of delivering the entire song for digital download after receipt of a certain fee sent by a minimum number of users (Dolan, 2000). A promotional campaign by the publishing house Simon and Schuster in New York City provides an example. Telephone kiosks on the streets of Manhattan offered to beam excerpts from the latest short stories by Stephen King to consumers' personal digital assistants. Loyal readers or other interested audiences could download approximately 400 words and share the sample with other owners of handheld computers (Elliott, 2002).[2] Music magazines could provide editorial content on artists when songs are purchased and downloaded on a mobile personal device.

The integration of personal messages and professionally produced content may provide another sharing option when mobile users receive the opportunity to make pieces of purchased mobile media available to friends and to comment on it. Such user-contextualized content may become subject to sharing among peers as well. Other forms of user contextualization may develop such as self selected and bundled songs that users share as a link list.

A third option is to make branded content available for sharing. Branded content is produced and financed by advertisers. It is attractive for users and it goes beyond advertising by disseminating real content (ECC, 2000). Firms from the consumer goods industry already produce content professionally as a means for brand building or customer relationship management. They could, for example, produce mobile games for sharing. If different games are available, consumers may appreciate access to the virtual storage capacities of mobile peer-to-peer communities due to device storage limitations.

In all cases of promotional sample content, user contextualized content, and branded content it is in the interest of the (media) company when users share these files. Full digital media files such as MP3 files may become interesting for mobile peer-to-peer platforms when the cost of transmission can be reduced and when peer-to-peer business models will be developed. Kortuem et al. (2001) suggest three forms of impromptu collaboration for mobile music MP3 file sharing: (1) face-to-face file sharing during personal encounters; (2) personal agents that act on behalf of users; (3) and institutionalized file sharing platforms that include authentication, security, and payment transactions. A commercial mobile peer-to-peer sharing model is likely to involve a digital rights management (DRM) system for mobile content. In this scenario, media companies could develop an institutionalized peer-to-peer platform that may allow paid content models. Figure 2 summarizes these two models.
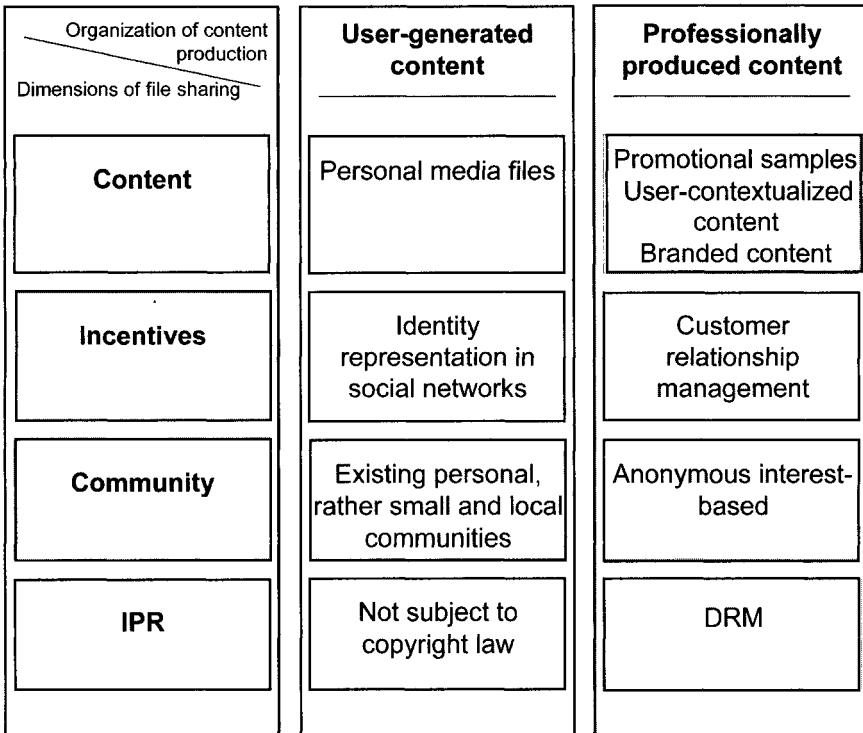
Organization of content production / Dimensions of file sharing	User-generated content	Professionally produced content
Content	Personal media files	Promotional samples User-contextualized content Branded content
Incentives	Identity representation in social networks	Customer relationship management
Community	Existing personal, rather small and local communities	Anonymous interest-based
IPR	Not subject to copyright law	DRM

Figure 2: Sharing dimension of mobile peer-to-peer content models

4 Mobile Peer-to-Peer Community Models

Community concepts, distinguished by the common values and common rules, shared resources and shared purposes that provide reason for the community, are a core construct in the social sciences. Mobile communities can be subject to ad hoc community formation (Rheingold, 2002); they can also be envisioned as extensions of real-life geographically based communities (Hollander, 2000) and of geographically dispersed virtual communities (Rheingold, 1995). For peer-to-peer applications this distinction may make a difference for community management strategies since peer-to-peer communities are often characterized by low community commitment and free riding problems.

4.1 Mobile Community Evolution

Mobile communities can be distinguished from online communities according to social scope and formation. Mobile communities can be both communities of anonymous members or a group of peers from an existing social network. When they relate to existing social networks, identity building within the social network may be an incentive for sharing and contributing to the community of friends since an essential reason for mobile phone and mobile community usage is to stay in close contact to friends and peers. Thus, buddy systems as implemented in instant messaging systems may become an interesting option for mobile community building. Mobile communities among anonymous members may form around shared interests such as lifestyle or health issues.

In the case of mobile ad hoc community formation, mobile communities are location dependent. One essential implication is that they enable consumers to act upon impulses. In the context and tradition of consumer research, impulse as opposed to habituated consumption decisions are subsumed under consumer decisions with low cognitive control which often involve emotions as well as an immediate action response to a stimulus (Stern, 1962; Rook, 1987; Kroeber-Riel & Weinberg, 1999).

Media companies have a longstanding tradition in building communities around their content. The first imagined community (Anderson, 1991) may have emerged with the subscriber base of a newspaper. Communities have also been introduced as a model for media content management on the Internet. The participants in these content communities create the context of the professionally produced content (Hummel/Lechner, 2001).

Content communities often evolve around strong media brands and can therefore be classified as brand communities. A brand community as introduced by Muniz & O'Guinn (2001) is a specialized non-geographically bound community that is based on a structured set of social relationships among admirers of a certain brand. Brand communities embrace the qualities from the concept of communities such as shared consciousness, rituals and traditions. For strong media brands, computer-mediated environments support the community creation around mass media content; individual users can devote messages, links, or Web pages to the community. Thereby, brand communities socially construct and shape media brand identities. Media companies may now expand their community models to mobile ad hoc communities around content versioning and ubiquitous media brand contact opportunities.

4.2 Mobile Peer-to-Peer Communities

Communities do not have to be formed around a belief or value, they can also be formed around an activity. Peer-to-peer content communities on the Internet have often evolved around music and movie files that can be searched and downloaded. However, it is debatable if a common use of an application can be called a community. The sociologist Brint (2001) offers the differentiation of interest based and activity based communities that is useful in this context. The formation around peer-to-peer file-sharing platforms is more activity based than belief based. Members share resources and purposes rather than common values. The personality representation, for example, is based on a nickname, the connection type, the number of shared files, and the (music) file properties. This user profile creates a sort of cultural capital that can be further segmented into sub-cultural capital when the specificity of the content raises (Poblocki, 2001). For example, in the Napster community, users with sub-cultural capital often gather in so called Hot Lists. However, the bonds between members are rather weak and fugitive. There is little incentive to develop stronger ties since individual goals can be attained without them. This results in a low sense of commitment and a weak brand loyalty towards the peer-to-peer community. Loyalty to Napster has decreased immensely after files were banned and the selection decreased (King, 2001).[3] Thus, peer-to-peer communities can be classified as activity based communities that exert weak ties on its members. The same may hold true for mobile peer-to-peer communities that represent (anonymous) ad hoc community members; in the case of a group of friends that constitute a mobile peer-to-peer commu-

nity the community loyalty is suggested to be higher due to strong ties from existing social networks (see Figure 3).

If file sharing is based on physical proximity in mobile peer-to-peer communities, the context of the file sharing is essential. Whereas PC-based peer-to-peer content sharing is executed with anonymous partners within the private space, trading partners are aware of each other when people come face-to-face since PAN exchanges only happen across short distances within close physical proximity. Physical proximity includes observing certain social clues, possibly talking, and it has consequences on politeness and trust (Kortuem et al., 2001). Since file sharing is based on short personal encounters or a possibly unstable mobile wireless network connection, the files should be of small size in order to be able to complete any sharing activity. In addition to volatile network connections, user attention in nomadic Internet environments is an even scarcer resource than in the stationary Internet; it might be occupied by other real-world tasks and unintentionally interrupt sharing processes.

Criteria \ Community Model	Fixed-line peer-to-peer community	Mobile ad hoc peer-to-peer community
Community elements	Activity-based location independent	Belief- / activity-based location (in)dependent
Personality representation	Nickname, connection type, number of shared files, file properties	Personal and personalized device represent users and lifestyle
Bonds between members	Weak, fugitive ties	Personal ties / weak, fugitive ties
Brand loyalty	Low sense of commitment	Strong sense of commitment in the case of personal ties
Sharing context	Stable	Volatile Impulsive

Figure 3: Characteristics of fixed-line and mobile peer-to-peer communities

The prominence of interpersonal communication management via the mobile phone suggests that an integration of professionally produced and user-generated content may be beneficial for the deployment of mobile communities. Mass media companies that intend to build mobile peer-to-peer communities may be able to unlock revenue opportunities by integrating pieces of their copyright protected content by means of interpersonal communications and user-generated content. For example, they can let users bundle music albums of self-selected (and potentially self-produced) songs they can share. When users purchase songs for download on their mobile device sound greeting to friends would be allowed.

Some prototype content models have been tested for mobile file sharing that integrate elements from interpersonal communications. In 2002, Orange Sverige, BMG Sweden, Compaq, and the IBM e-business Innovation Center developed a 3G music prototype (van Impe, 2002). It functioned like a music encyclopedia and personal jukebox.[4] The pilot test 'x-files' allowed 30 test users to use the service for one day. A client server architecture that integrated a digital rights management system allowed consumers to buy digital licenses. Users were able to select, listen to, search, organize and exchange music, video, voice, and text content. Parts of the songs could be sent to friends via IM or e-mail. Recording functions for user-generated sounds could be activated by dialing a certain number and record the sound. Whereas older test users tended to be more interested in a jukebox application, younger test users preferred to play with the application and communicate it immediately to their friends. Orange sees its own core value in creating communities around that content (Neumann, 2002). Another emerging mobile peer-to-peer application is the Japanese Gnutella project, http://jnutella.org. It is deploying Gnutella on i-mode mobile phones where the results of a search are tailored to mobile phone interfaces.

File sharing of mobile mass media content that integrates forms of interpersonal communications between members of a social network may become a promising model for mobile communities. Yet, mobile file sharing may have its greatest potential within a small world social network based mobile community in order to exchange personal media files.

4.3 Community Management of Mobile Peer-to-Peer Communities

In peer-to-peer communities, free riding is a fundamental problem. Almost 70% of Gnutella users share no files, and the top 1% of sharing hosts return nearly 50% of all responses (Adar & Huberman, 2000). This phenomenon

is related to the problem of securing enough cooperation in large and anonymous systems.[5]

A possible solution to free riding is to restrict membership for mobile peer-to-peer content communities, for example, limit it to mobile buddy lists. Asvanund et al. (2001) analyze the optimal size of a mobile wireless peer-to-peer network and suggest multiple small networks instead of a single monolithic network. In their model, they take three elements into account: the amount and desirability of content provided by the user, the size and frequency of downloads initiated by the user, and the size of networks in terms of users and capacity. They model positive network externalities as new selections of content provided by additional users. Negative network externalities are modeled as network congestion caused by additional users.[6] Marginal value of additional users is declining and the marginal cost is increasing with the number of users of a monolithic network.

Another option for mobile peer-to-peer community management is to set up a market based architecture that allows peers to buy and sell resources such as processing resources or bandwidth capacity. This is possible through the introduction of micro-payments (Golle, Leyton-Brown, & Mironov, 2001). The imposition of financial transfers abstract from altruistic reasons for sharing and contribute to reaching network equilibrium. Micropayment mechanisms can, for example, reward users for uploading and charge them for downloading.

Pricing has also been applied to transit traffic in wireless peer-to-peer networks (Chandan & Hogendorn, 2001). In these peer-to-peer network models each user's mobile device must dedicate some of its bandwidth and battery power to facilitating the transit traffic of other users. The findings suggest that organizing peering through a club may be the best solution to possible congestion problems. It could internalize the network externalities by instituting an entry fee or a limitation on bandwidth use. The club could be run for profit or it could be a voluntary association with a restricted number of slots.

The implications for wireless operators and media content providers that derive from these characteristics of mobile peer-to-peer community management suggest to abandon generalist content strategies and to specialize content offers. Mobile peer-to-peer content communities are likely to introduce optimal membership rules as well as pricing mechanisms to avoid free riding and congestion externalities.

5   Emerging Policy Implications

Two dominant policy issues emerge, the first affecting copyright issues, the other one addressing security and privacy.

Mobile DRM systems are currently developed by mobile operators, content providers, and independent third parties. The discussion about copyright infringement from fixed-line peer-to-peer applications (Greenstein, 2001; Picot, 2004) extends on wireless and mobile networks and devices when professionally produced media content will be available for download to mobile devices as well as for mobile streaming. Yet, when mobile content is regarded as a means to support and expand revenue generation in the core media brand offer, media companies may have an incentive to allow for open platforms and mobile sharing processes. Moreover, consumer choice on the use of digital media files on more than one device is an essential concern from a fair use perspective. Another issue is the liability of third parties, since existing copyright case law imposes liability on third parties for the infringing act of others (Greenstein, 2001). If a mobile user happens to become a frequently used node in an ad hoc network this user may be regarded as a (temporary) central authority.

Mobile peer-to-peer community models also raise data security and privacy concerns with opening a mobile device to the public for accessing or routing data. There is increased danger of mobile virus spread and data theft with open mobile devices. These concerns may contribute to favor restricted mobile peer-to-peer community access. When more sensitive data, for example, transaction and payment information, is stored on mobile devices security concerns add to the privacy issues. In the case of mobile payments for file sharing, contracts also need to consider the dynamically changing network topography and potential transfer failures.

6   Conclusion and Outlook

Mobile peer-to-peer communities face technological challenges such as restricted resources on the mobile computing device as well as narrow bandwidth and unreliability of the wireless link. Yet, instant and ubiquitous access to virtual storage or ad hoc community formation may offer incentives for file and information sharing. A mobile Napster is unlikely to emerge due to the constraints of mobile devices and network capacities. Yet, the social dimensions of mobile peer-to-peer communities are interesting for the discussion of alternative applications. They may take advantage of the ad hoc community

formation capabilities, social networks of mobile users, social aspects of physical proximity, and new interaction patterns.

Different content models exert much influence on user's incentive to share and contribute to mobile peer-to-peer communities as well as their behavioral patterns. User generated content such as digital pictures, sound greetings, or video recordings may become popular properties for sharing within social networks. Since the mobile phone is increasingly used as a means of self-expression, its nature suggests personal file sharing and using mobile peer-to-peer platforms as a means of virtual storage. Mobile operators have an interest in these forms of exchange, because it drives mobile data traffic to their networks. Professionally produced media content, on the other hand, may be shared in the form of links that point toward files that will be available for later download on a different device or via a different network. Media companies can organize sample content sharing via mobile peer-to-peer communities in order to strengthen brand loyalty and revenues in other offline and online media channels. Branded content, media content that is financed by an advertising client, may offer an even better proposition for mobile peer-to-peer sharing since the advertiser is interested in the viral effects from mobile users.

Free riding problems in peer-to-peer environments suggest the need for community management. Rules for sharing could consist of micro-payment models or membership restrictions. According to user preferences, mobile peer-to-peer communities can be efficiently managed in the form of clubs based on special interests. However, in mobile peer-to-peer communities that are activity based and characterized by weak ties, free riding may still be a problem.

The role of mass media providers can lie in the community platform provision and management of mobile peer-to-peer communities. It is limited for user generated content models since mobile operators will have a far greater incentive to provide community platforms for these content models. In the case of professionally produced content, however, media companies can play a role in using their brand strength to offer community platforms to targeted user groups. Their strongest proposition is the cross-media integration of mobile community models with their existing online communities and the stimulation of cross-media audience flows between different media. When media companies manage to build a marketplace for peer-to-peer community models, emerging cross-network approaches (Feldmann, 2005) are yet another alternative that will offer users more choice with regard to price and quality of service.

Endnotes

[1] Because these resources are subject to changing IP addresses, peer-to-peer transcends the Domain Name System (DNS) layer and reverts control back to the PCs. That distinguishes this definition from the peer-to-peer definition in the 1970s and 1980s. Then, peer-to-peer technology connected mainframe computers that were permanently connected and had a permanent IP address. This changed with the growing number of PCs connecting to the Net, see Fattah (2002), p. 20.

[2] This sharing process did not happen via a mobile wireless peer-to-peer network yet, but with the conventional PDA capability of beaming content.

[3] In April 2001, Napster use fell by nearly 36 percent from the previous month, according to a study by Webnoize research, see King (2001).

[4] The following information is based on a telephone interview with Orange's business development manager Frederick Neumann, conducted on March 27, 2002.

[5] Napster users have even been witnessed to misrepresent the speed of their network connection in order to discourage other users from connecting to them, see Adar & Huberman (2000), p. 7.

[6] Research suggested positive network externalities for song availability with up to 8,000 users. Negative network externalities increased exponentially as the number of users approached the hypothesized capacity of the network, see Asvanund et al. (2001), p. 3.

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